PRODUCTIVE STRATEGIES IN AN UNCERTAIN ENVIRONMENT: PREHISTORIC AGRICULTURE ON EASTER ISLAND

Christopher M. Stevenson[1], *Thegn Ladefoged*[2] *and Sonia Haoa*[3]

[1]*Virginia Department of Historic Resources, Petersburg, VA 23805;*
[2]*Department of Anthropology, University of Washington, Seattle, WA;*
[3]*Sonia Haoa, Isla de Pascua, Chile*

INTRODUCTION

The unpredictable nature of a key environmental resource (e.g., moisture) is often viewed as a major variable that guides economic decision-making and the form of the social organization required to implement adaptive strategies that will ensure the survival of the population. Several authors have recently argued that environments characterized by higher uncertainty (e.g., risk of crop failure) will exhibit a greater tempo of changing organizational forms and an overall higher level of organizational complexity. (Ladefoged 1995; Graves and Ladefoged 1995; Dunnell 1999; Ladefoged and Graves 2000; Kirch 2000; Hammon 2001; Hunt and Lipo 2001). In these high-risk environments the construction of chiefly sponsored monumental architecture can suppress population numbers to below critical levels. Energy that could be expended on increasing agricultural production, thereby leading to increases in population levels, is diverted into "wasteful" activities, such as monumental construction. This has the two-fold advantage of suppressing population numbers to levels sustainable during environmental perturbations and maintaining a pool of labor that can be diverted into subsistence activities when necessary. In addition, monumental architecture can be used to bolster ideological beliefs that are necessary for maintaining an integrated chiefly polity (Earle 1997). These polities can often provide opportunities for resource buffering during periods of environmental perturbations (Ladefoged 1995). The implementation of labor intensive forms of agricultural intensification in response to marginal and uncertain environmental conditions require that the authority of the hierarchy be strong in order that production above the household level can be obtained.

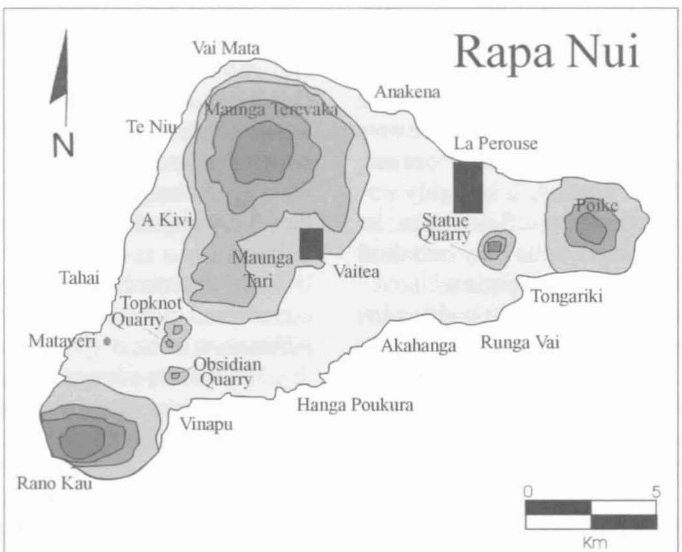

Figure 1. Map of Easter Island (Rapa Nui) showing the Vaitea area (center) and the Heki'i area near La Pérouse.

In this paper, we look at how the practice of prehistoric agriculture may have contributed to the development and maintenance of a hierarchical social organization. In our approach to understanding the prehistoric agricultural system, we will look at how the prehistoric Rapanui utilized and changed the island landscape. These landscape modifications on Rapa Nui and elsewhere were developed in response to fundamental environmental constraints within which agriculture was practiced. This was a dynamic and continuous process. During the settlement of the Pacific, human colonizers initially took advantage of natural landscape features such as wind-protected locations with plentiful supplies of fresh water. These advantageous settings were used for early settlement and agriculture. The later expansion of gardens and field systems significantly modified the ecological structure of many islands (Kirch 1997, 2000; Flenley and King 1984; Flenley et al. 1991) and the surface soils that support the living biota. The elimination of habitat and soil erosion have been cited as two outcomes of an expanding agricultural system. This process increased agricultural risk and required innovation within the subsistence system to maintain required production levels. It is this process of innovation that we will investigate through an examination of the Rapa Nui landscape.

In this paper, we will examine the Rapanui agriculture system and ask three questions:

1) What were the risk factors behind rainfall agriculture and how did the risk vary across the island landscape?

2) How did agricultural use of the landscape vary in response to different habitat conditions?

3) What is the chronology of prehistoric agricultural technologies and landscape use?

THE RAPA NUI ENVIRONMENT

Three volcanoes form the Rapa Nui landscape. Mt. Terevaka is the principal shield volcano that forms the central mass of the island. Strato volcanoes at the southwestern and southeastern tip, Rano Kau and Poike respectively, form the other elevated landforms. Mt. Terevaka reaches a height of approximately 450 m. A low coastal plain connects the three volcanoes along the western, southern and eastern margins of Mt. Terevaka

(Figure 1).

Rapa Nui is located within the southern, temperate latitudes of the Pacific Ocean and a marked seasonality occurs each year that is generally referred to as the rainy season and the dry season. Rainfall averages over 1000 mm a year in the coastal zone near the town of Hanga Roa but much of this rain (359 mm) falls in the wet season (April-June). During the warmest period of the year (December-February) an average of 240 mm of rain is reported at the Mataveri weather station. An analysis of these weather records (1972-1997) by Hunt and Lipo (2001) reports that the variation around the mean is great and reflected by a high coefficient of variation (0.17-0.26). There appears to be no periodicity in these short-term rainfall records, and the occurrence of dry periods appears to be unpredictable.

The high elevations on the island surface and predominant northwest-southeast wind patterns create an orographic rainfall pattern. No rain gauges are present on the island other than at the near sea-level location of Mataveri (Figure 1) but a predictive model by Honorato et al. (1991) proposes that up to double the amount of rainfall characteristic of coastal regions will fall in the upper regions of the three volcanoes beginning near the 200 meter elevation. The Poike region appears to have been used for agriculture as there is little evidence of prehistoric settlement. As a result only about a sixth of the island surface area benefits from the higher rainfall levels. Although the higher rainfall reduces the unpredictable nature of this upland region, the same model also predicts a decrease in temperature of 0.6-1.0° C for every 100 m rise in elevation. This may have slowed crop maturation rates. Similarly, higher elevations may be associated with greater wind velocities, which increase evaporation and thus reduce available moisture. Taken together with lower temperatures, these factors may partly offset the full benefit of increased rainfall amounts.

The past volcanic activity has also created the excessively drained soils present on the island today. The near surface soil A-horizons are characterized by soils that have formed from ash falls (Louwagie and Langohr 2002). As a result, it is highly porous with about 50% of the volume consisting of air space. In some areas of deeper soil, B-horizons tend to be clay-enriched and have a blocky pedogenic structure. Beneath this is a characteristically loose, regolithic soil with little pedogenic structure (Wozniak 2000). This strata may occur almost directly under A-horizons in areas with little soil development. The clay-rich soils may help to hold moisture at deeper levels but in shallow areas the lower C-horizon does little to retain soil moisture. In general, the soils on Rapa Nui exacerbate the problem of limited moisture.

These data show that while the entire island may be characterized as high risk for agriculture, there are some areas at higher elevations that may have been less unpredictable in terms of rainfall occurrence. The added moisture above 200 m elevation could have extended the period of wetter winter/spring weather for weeks over that encountered near the coast. The implications for agricultural production and the organization of production are significant. If the rainfall pattern is compared with the distribution of island political units (Stevenson in press, Figure 2), we see that not all chiefdom districts had access to the wetter interior regions. It is therefore reasonable to expect that the technology of production and landscape use will differ between the dryer Heki'i, Mahatua, Tongariki, Hanga Poukura, Vinapu and Tahai districts and the Vaihu, Akahanga, Tepeu and 'Anakena districts that have sizable upland regions within their boundaries. The Tahai and Vinapu district have access to moister areas near at the top of the Rano Kau volcano but the size of the productive zone is small.

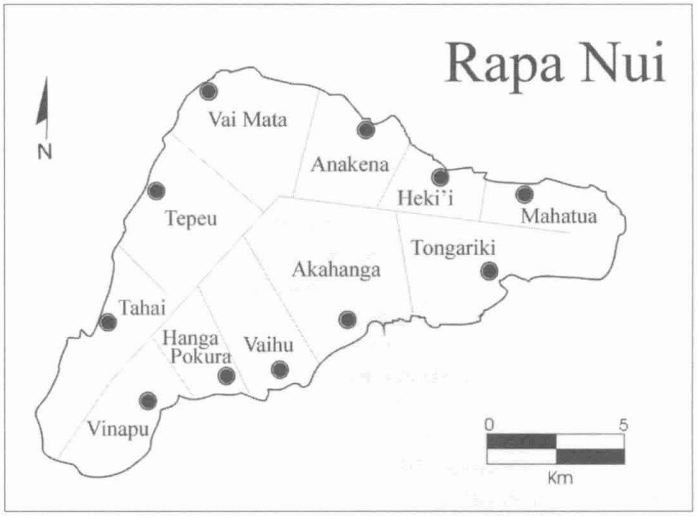

Figure 2. Rapa Nui chiefdom districts circa. AD 1500 (after Stevenson in press).

The Rapa Nui Agricultural System

The prehistoric agricultural system on Rapa Nui relied exclusively on rainfall. Only a few years ago the location of Rapa Nui gardens and agricultural field systems could not be identified by either archaeologists or the remaining indigenous population. Only the frequently occurring circular stacked stone structures (*manavai)* and planting wells (*pu*) were associated with agricultural production. Yet the dryland production system that fed a population numbering in the thousands for nearly a millennia was assumed to have been large in scale and intensive in form. In retrospect, this inability to find evidence of past agriculture was a problem in landscape interpretation. The subtle indications of field systems had not been recognized.

However, a series of surveys and test excavation programs (Stevenson and Cristino 1986; Stevenson 1997; Stevenson and Haoa 1998; Stevenson et al. 1999; Wozniak 1998a, 1998b, 2000) has identified a variety of morphologically distinct agricultural features found throughout the island. Stevenson et al. (1999:803-804) note eight types of agricultural features and these can be redefined as six discrete types:

1) *Mulched soils* are areas with small (2 to 20 cm) rocks intentionally mixed into the subsurface sediment to depths of 30 to 50 cm. The source of the lithic mulch includes rock intentionally broken off surrounding basalt outcrops, and rock eroding from the underlying bedrock. The lithic mulch would help to conserve moisture, ameliorate excess soil temperature fluctuations, and protect the garden soils from wind evapotransporation (Stevenson et al. 1999:809).

Correction: page 18, second paragraph, third sentence should read "The Poike region appears not to have been used for agriculture as there is little evidence of prehistoric settlement."

2) V*eneer surfaces* consist of areas were a relatively uniform 20 to 30 cm layer of rocks has been spread over the ground surface. The rocks are usually from basalt outcrops in the immediate vicinity that have been intentionally broken apart. The cover of rock would aid in rainfall permeating the surface, would reduce evaporation providing higher moisture levels, and inhibit weeds (Stevenson et al. 1999:809).

3) *Stacked boulder concentrations* are areas where a veneer of rock has been spread over the surface but additional stacking of rocks within the garden occurs. The stacked rocks form low windbreaks for the cultigens. Again, the rocks usually derive from basalt outcrops in the immediate vicinity that have been intentionally modified. The stacked boulders and associated veneer would have the advantages of veneer surfaces, with the additional benefit of creating windbreaks for the cultigens.

4) *Pu* are steep sided depressions, ca. 50 to 60 cm in diameter, located in rocky areas. The depressions extend to the soil layer below the rock, and with additional vegetative mulch would have provided a planting medium conducive to water retention. The rocky areas are the result of people breaking apart basalt outcrops or are natural lava flows.

5) *Manavai* are 2 to 6 m long, 70 to 150 cm high, stacked stone garden enclosures. These would have protected fragile plants such as banana from wind damage and reduced evaporation.

6) *Planting circles* are formed by rings of small stone 1.0 to 1.5 m in diameter and define the perimeter of a planting pit. With the addition of vegetative mulch, the pits would have provided a localized soil medium conducive for plant growth.

The precise cultigens grown in these agricultural features is unknown, but we hypothesize that sweet potatoes were grown in the mulched soils; dryland taro, yams, and possibly sweet potatoes were grown in the veneer surfaces and stacked boulder concentrations; dryland taro and yams were grown in the *pu*; bananas and perhaps young propagation plants were grown in the *manavai*; and dryland taro, yams, and sweet potato were grown in the planting circles.

These six types of agricultural features are differentially distributed throughout the island. In combination, these features form the gardens and field systems that would have fed the substantial prehistoric population. The once thought haphazard distribution of outcrops and boulder can now be seen as well articulated and strategically placed growing areas on the terrain. The investigation and interpretation of rock garden varieties permits a reconstruction of past agricultural technologies and landscape use. We compare the dry lowland Heki'i District and the moister Akahanga/Vaihu (Vaitea) upland region to examine differences in settlement and agricultural technology.

Heki'i District

A comparison of the landscape between a dry region such as the Heki'i District and a moisture upland area in the Akahanga/Vaihu Districts reveals several similarities, as well as striking differences, in settlement and methods of farming. The archaeological survey data and geomorphological soil assessments (Stevenson et al. 1996, 1997, 2000) shows that field systems covered a vast amount of the landscape in the north coast Heki'i District (Stevenson and Haoa 1998; Stevenson et al. 1999) (Figure 3). The distribution of agricultural features comprising different garden types can be used to define three general zones of production.

Coastal: This zone is below 30 m elevation and is situated within 1000 m of the coast. On the heavily settled coastal plain, the numerous domestic settlements consist of houses, chicken houses, earth ovens, and are associated with small household gardens and larger field systems, both of which consist of

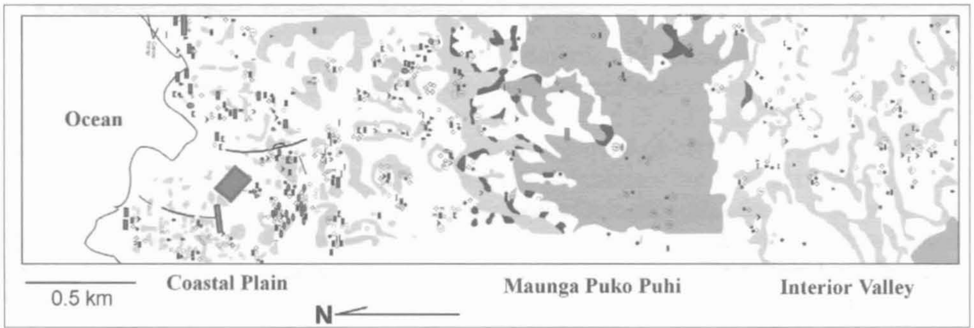

Figure 3. The distribution of settlements and agricultural fields in the Heki'i District

manavai, veneer surfaces and stacked boulder concentrations. Domestic settlements tend to be located at the margins of their gardens while the larger field systems have few adjacent settlements.

Lowland inland: At a distance of approximately 1000 m from the coast at an elevation of ca. 50 to 80 m above sea level, a large hilltop plantation is encountered on top of Maunga Puko Puhi. This flat hilltop is heavily mulched with small basalt stones that cover a shallow (50 cm deep) agricultural soil many hectares in size. Settlement consists primarily of low-density lithic tool scatters that represent temporary dwellings. The houses of elite personnel and a small shrine (*ahu*) have also been identified in this zone. They are hypothesized to represent a managerial presence.

Lowland interior: Further inland at a distance of about 2 km from the coast and located on the northern edge of Maunga Puko Puhi lies an interior valley. Permanent domestic settlement with associated veneer surface and stacked boulder concentration gardens resumes although the overall density of settlement is lower than the near coastal region. The gardens include both small household gardens and larger field systems.

Akahanga/Vaihu District

An intensive archaeological settlement survey has been conducted in the Akahanga/Vaihu districts and has recorded many hundreds of archaeological features (Cristino et al. 1981; McCoy 1976). We have recently re-surveyed a portion of the upland Vaitea area of these districts (Stevenson et al. 2002). The results of these surveys indicate three general zones of land use.

Coastal: This zone consists of the lowland coastal area, extends inland ca. 1.75 km, and includes the slope up to an elevation of ca. 50 m above sea level. The settlement in this area is similar to coastal zone in the Heki'i District and consists of permanent architectural features such as houses, habitation caves, earth ovens, and chicken houses (Cristino et al. 1981, Stevenson 1984, 1997). A number of smaller household gardens and larger field systems consisting of *manavai*, veneer surfaces and stacked boulder concentrations are known to exist but have not been surveyed.

Lowland inland: This zone extends from ca. 1.75 km to 4 km inland between elevations of 50 to 150 m. Settlement is similar to the coastal zone, with the exception that the density of residential and agricultural features is considerably less.

Upland interior: The archaeological features in the upland Vaitea survey area extend from ca. 4 to 6 km inland, above an elevation of 150 m, and consist of rectangular house foundations, rectangular platforms of crude field stone, u-shaped structures, cleared walkways with stone borders, circular enclosures with low perimeter walls and open hearths. Noticeably absent are features such as larger house patios, chicken houses, *manavai* and earth ovens. In the Vaitea area, these surface features are associated with an undulating weathered lava flow consisting of numerous ridges and swales defined by projecting basalt outcrops. Prehistoric gardens of varying dimensions consisting of veneer surfaces and stacked boulder concentrations are located within the walled enclosures and in the protected areas at the base of slopes and between the basalt outcroppings. The rectangular houses are typically associated with these agricultural fields.

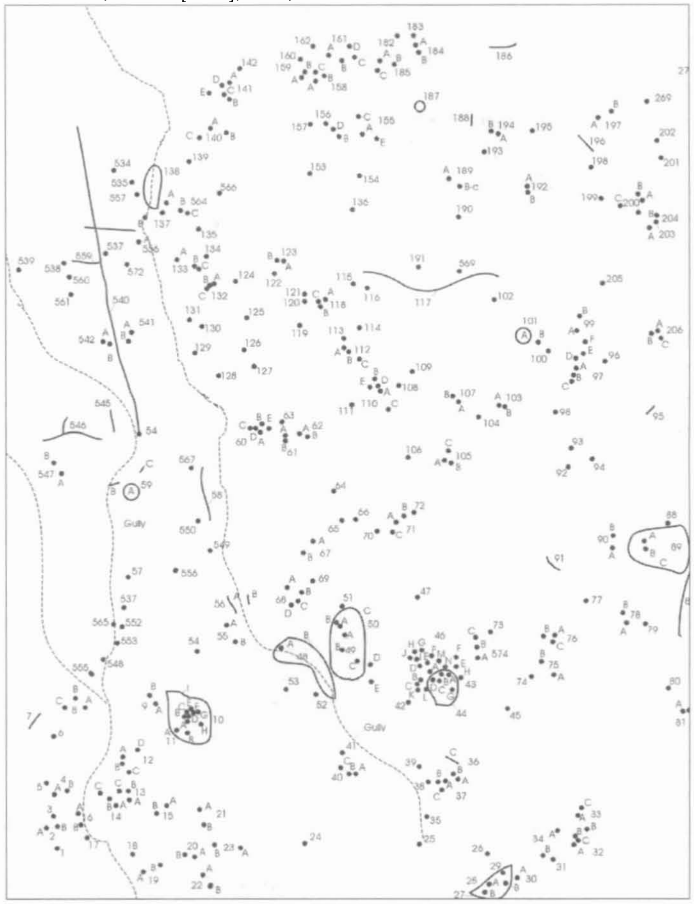

Figure 4. The distribution of settlements in the Vaitea upland region (after Cristino et al. 1981).

THE CHRONOLOGY OF LANDSCAPE USE

The body of chronological data in the form of radiocarbon and obsidian hydration dates has grown significantly in the last 15 years (Martinnson-Wallin 1994; Stevenson 1984, 2000; Stevenson et al. 2000). The context of these dates are not only from *ahu* and domestic sites but also from agricultural features. Collectively, these data allow us to see where the island landscape was occupied in the past and how it was modified.

A settlement pattern model based on earlier work in the Akahanga District and the upland interior Vaitea (Maunga Tari) area proposed an early (ca. AD 800) settlement for coastal regions and a gradual expansion from core areas to other near shore regions. The building of new dwellings gradually expanded inland and the first forays into upland regions occurred around AD 1250. By AD 1400-1500 the uplands were routinely utilized (Stevenson 1997) and continued to be farmed until the early AD 1700s. In the early AD 1700s the upland regions were abandoned and agricultural production was conducted at lower elevations.

The use of the landscape in the Heki'i District shows a similar dynamic pattern of landscape use. The earliest settlement was also along the coast. Excavated ceremonial structures (*ahu*) on the north coast in the adjacent 'Anakena District date to AD 900-1000 (Skjølsvold 1994). Domestic sites in the coastal plain were long-term and stable residence locations with occupational spans of over 500 years (AD 1300-1800) (Stevenson et al. 1996). In contrast, the heavily mulched hilltop fields located about a kilometer inland were only used for several centuries (ca. AD 1400-1700) and represent an effort to significantly increase production near the apex of chiefdom complexity by the introduction of elite managed plantations (Stevenson et al. 1999). These fields are in production at the same time as the moister upland regions and are a direct expression of an intensified agricultural system. Further inland within an interior valley, initial settlement was early and began in the AD 1100-1200s and continued until it too was abandoned in the early AD 1700s. From this time on, virtually all of the island population was living on the island coastal plain.

These data suggest that the coastal zone was occupied continuously from initial settlement of the island at ca. AD 800. The relatively low rainfall in this zone would reduce agricultural productivity, but the zone had the advantage of being closer to marine resources. The lowland inland zone was not intensively used until much later, beginning around AD 1400 and extending to ca. AD 1700. This zone receives less rainfall than the uplands and would have required intensive amounts of labor devoted to lithic mulching to make it agriculturally productive. The lowland interior zone apparently had greater agricultural potential using extensive techniques than had the lowland inland zone, and was utilized relatively early from ca. AD 1100 to 1700. The upland interior zone receives the highest rainfall, but the greater distance to the coast, the increase in wind velocity (thereby increasing evaporation and reducing the amount of available moisture), and the lower temperatures made it less desirable for agriculture and it was not initially used until AD 1250, and not extensively used until ca. AD 1400.

DISCUSSION

The archaeological remains from the Akahanga/Vaihu (Vaitea) area were initially used to develop the first regional settlement model for Rapa Nui (Stevenson 1997). It was based upon the concept of the Hawaiian *ahupua'a* where each sub-district population segment had access to a strip of land from the coast to the interior and the full range of resources contained within it. Implied in this model is that the resources available to each population segment were more or less equal. On Rapa Nui the variation in elevation and moisture availability suggests that some chiefdom districts had more favorable habitats within their boundaries.

It has been proposed that prior to chiefdom collapse in the 17th century, the political center of each district was located near the largest ceremonial center (*ahu*). A cluster of chiefly houses was located immediately inland of the *ahu*. Habitation sites of non-elite personnel were located inland of the coastal sacred zone up to an elevation of approximately 150 m. Settlement became less frequent with increasing elevation and eventually changed to the settlement characteristic of the upland interior Vaitea area. We now know that the rectangular houses represented temporarily occupied dwellings, some of which may have been the residences of elite managers overseeing agricultural production (Stevenson 1997; Stevenson et al. 1999).

Archaeological survey in the Heki'i District has increased our understanding of how the landscape was utilized and requires that the initial model be revised to account for districts that do not have the moister upland regions. The similarity in the coastal settlement pattern between the Heki'i and Akahanga Districts suggests that the coastal zone in both areas included household gardens and lowland field systems. In contrast, further inland on the edge of the coastal plain of the Heki'i District were large and labor-intensive plantations on low hilltops that were managed by elite personnel and where non-elite occupations did not require permanent surface architecture. Further inland, low-density settlement with permanent architecture and associated field systems resume. These latter two areas served as the main production regions in Heki'i District where surplus food supplies were generated.

Both the upland region and the hilltop plantations reflect intensive forms of agricultural production. The upland interior Vaitea area consists of rock gardens or field systems that utilized a weathered and undulating lava flow for protection against the wind. Millions of stones were intentionally brought together to form a protective rock distribution in veneer surfaces and stacked boulder concentrations. Our observations note that the outcrops were also dismantled to provide additional stone. These gardens were removed from the coastal areas by at least 4 kilometers and would have involved significant travel time to tend the fields and significant transport costs to move the sweet potatoes and taro to lowland households.

The hilltop plantations in the Heki'i District were located only about 1-2 km from the coast thereby reducing travel and transport costs. However, the level of effort invested in rock garden construction was significantly greater. Here, the rock cover is a deep lithic mulch of billions of small stones over a shallow soil. Individual planting pits penetrated into regolithic C-horizon in an attempt to create a suitable growing environment with higher moisture content.

It seems clear now that the development of labor-intensive field systems correlates well with the occurrence of larger ceremonial complexes. In the early part of Rapa Nui prehistory we hypothesize that *extensive* forms of agricultural production were practiced in the coastal regions (from AD 800), in the lowland interior (from AD 1100) and in the upland interior (from AD 1250) and was probably based on dryland taro cultivation. Yields from this form of production would not have resulted in large surpluses. We propose that *intensive* forms of agriculture in each of these same zones occurred after AD 1400 with the later introduction of the sweet potato. This tuber reached east Polynesia around AD 1000 (Kirch et al. 1995) and was later taken to outlier islands where its cultivation produced yields well above that required for subsistence needs.

The architectural trajectory on Rapa Nui appears to support our general scheme. Although large formal *ahu* are present by AD 1000-1100 (Skjølsvold 1994) many of the largest structures were built in the AD 1400s to AD 1600s (Martinsson-Wallin 1994). The presence of landforms in two parts of the island devoted to intensive agricultural production beginning around AD 1400 and ending around AD 1700 is evidence to support the proposition that corporate work efforts required a larger amount of food than could be produced at the household level. However, this elevated production had to occur in an uncertain environment and required extraordinary modifications of the landscape to be realized. We propose that the return on labor investment was very low and required an ideologically strong and strictly ranked hierarchy, one that emerged in only a few centuries after settlement.

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